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THE INVENTION OF A NEW TYPE OF FRICTION SENSITIVITY APPARATUS

RESEARCH AND DEVELOPMENT DEPARTMENT

U. S. NAVAL AMMUNITION DEPOT - CRANE, INDIANA

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FRICTION SENSITIVITY APPARATUS

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ABSTRACT

A new type of test apparatus has been invented which obtains an absolute value in foot-pounds for the friction energy required to ignite explosives, pyrotechnics, propellants and other high energy compositions.

The device obtains the frictional energy of ignition spinning a rod on the sample held in an alundum sample ho[illegible]. This energy is calculated from the torque load, the defle[illegible] the revolutions per minute and the time to fire. Reproduc[illegible]bility of test results using duplicate samples is within [illegible] 1% to 2% range.

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INTRODUCTION

Friction is one of the most common causes of explosions and fires induced in pyrotechnic compositions and explosives. It is very essential that a friction sensitivity value be found for all compositions in these two categories. A knowledge of the degree of sensitivity of the compound or composition is used in setting up safety procedures in manufacturing, testing, handling, storage and transportation.

Investigation of existing methods for determining friction sensitivity disclosed that the standard apparatus for determining friction sensitivity consisted of a swinging pendulum fitted with either a steel or fiber shoe which is permitted to sweep back and forward across a sample placed on a grooved steel friction anvil. If the steel shoe demonstrates that two materials are of the same degree of sensitivity, the fiber shoe can often be used to show differences. This test apparatus is a fairly massive piece of machinery as the shoe weighs 20 kilograms.

Consultation with members of an interservice pyrotechnic research committee led to the conclusion that existing friction sensitivity testing apparatus were not capable of reproducing reliable test data. The swinging pendulum also induced an impact factor into the test results. Some specialized test devices using the pendulum principle also contained a spring

whose tension would change with time, and the spring was difficult to duplicate.

A friction sensitivity test apparatus was needed which could be duplicated from drawings so that different test facilities could manufacture the device and with it determine meaningful, reproducible friction sensitivity test data on pyrotechnic compositions and explosives.

The apparatus described in this report (Figure 1) was devised to meet the above requirements. It is called the Roto-Friction Test Apparatus.

DESCRIPTION OF THE APPARATUS

The device consists of an alundum sample holder (Drawing No. RDT 2883) mounted in an aluminum cam torque converter (Drawing No. RDT 2822-2837) turning on bearings to reduce inertia. A calibrated weight is attached to the cam by a line run over a grooved drum. A table converts the cam's degrees of revolution to inches so that the torque is read in ounce-inches.

A friction rod (Drawing No. RDT 2884) spins on top of the sample held in the alundum sample holder. A selected force is applied to the rod by means of weights as indicated in Figure 1. A variable speed electric motor or a motor fitted with a variable belt drive turns the rod at the desired revolutions per minute. The r.p.m. are checked with a strob-o-scope. Any suitable bench drill press may be used as the driving force for the rod.

The test apparatus is operated behind a 1/2" safety glass.

PROCEDURE

Place weights on the friction rod to produce the desired force. Select the desired r.p.m. and the torque load. Place a sample weighed to 20 ± 1 milligram in the alundum sample holder. Lower the safety shield.

Start the motor. Lower the spinning rod to rest on the sample and start the timer at the same time. At the moment of fire stop the timer.

If the time of fire is too short to be read, reduce the weights on the friction rods or the r.p.m. A desirable range, not always obtainable, is a firing time of 2 to 10 seconds.

The torque reading in degrees should be between 5° - 355°. The torque reading in this range may be obtained by adjusting the r.p.m., the weights applied to the friction rod, the torque weight or a combination of these factors.

Fnter the factors defining the conditions of the test and the test data in the following table:

Torque						
Load Oz.	Deflection Degrees	R.P.M.	Time to Fire Sec.	Lbs. Load on Friction Rod	Ignition Energy Ft-Lbs	Notation of Observation

CALCULATIONS

The energy required to decompose the sample will be noted as a flash of fire, a cloud of smoke or as an audible report. This energy is calculated in foot-pounds by use of the following formula:

Formula No. 1 $$E = \frac{\pi W t T}{30} \text{ Ft.-lbs.}$$

W = the angular velocity in revolutions per minute of the rotating friction rod.
t = time of rotation in sec.
T = Torque on the rod in ft.-pounds

Since the torque data is obtained in ounce-inches, the product of these two values is converted to ft.lbs. by dividing by 192.

A typical calculation is given from the data as collected below:

Torque Load Oz.	Deflection Degrees	RPM	Time to Fire Sec.	Lbs. Load on Friction Rod
4.27	318°	2400	2.2	10

The load on the friction rod is entered as one of the factors defining the conditions but it is not used in the formula.

$$E = \frac{\pi \, 2400 \left(\frac{*2.46158 \times 4.27}{192}\right) 2.2}{30} = 36.63 \text{ ft.-lbs.}$$

*This figure represents the torque arm length in inches. At 0° rotation the arm length is 1.25 in. Degrees deflection X .00381 + 1.25 in. = the arm length in inches. In this particular case 318° X .00381 + 1.25 = 2.46158 in. To avoid

calculations Table No. 1 has been made which translates the degrees of deflection into a torque arm length in inches. The table ranges from 0° to 360° by 5° intervals.

Formula No. 1 assumes a constant torque as a condition of the test. The test data to date, from most of the tests, leads to the conclusion that this assumption is true. There have been two exceptions noted so far, smokeless powder and phosphorus. In the case of these two compositions, the torque reaches a first peak, the material melts and the torque decreases due to the liquid state's lower coefficient of friction. The torque rises to a secondary peak, smaller than the first, at which time firing occurs.

In this case of a variable torque the quantity t T in the formula may be replaced by:

Formula No. 2 $$E = \frac{\pi W A}{30}$$

A = the area under the curve obtained by graphing torque (T) in lb ft. VS time (t) in seconds.

CONCLUSIONS

Examination of the test results in Tables 2 and 3 demonstrates the validity of the test results obtained by the new friction sensitivity test apparatus. The load on the friction rod, the revolutions per minute and the torque load may be varied singly or in combination without appreciably changing the value of the friction ignition energy.

Examination of the test data in Table 4 reveals 10 sets of duplicate sample results. The variation from the average of each of these duplicates was not more than 2%.

The friction rod in the present apparatus is 1/4" drill rod steel tempered to Rockwell 58-60C. This rod acts as a heat sink. To avoid this factor a ceramic rod will be substituted which will be manufactured from Cornings' super strength glass. Substitution of a non-heat conductive material will apply more of the frictional heat to the sample being tested. This should result in slightly lower readings in foot-pounds of energy.

If it is necessary to obtain the energy in terms of the variable torque it will be obtained by means of an electronic torque recorder.

In the case of a variable torque the first peak torque represents the initial energy required for a phase change in the material undergoing test. This peak torque is followed by a decrease in torque with a subsequent rise to a secondary,

lesser torque peak.

Without the energy needed to reach the initial peak no reaction could take place; therefore this energy can be accepted as the frictional energy necessary to initiate ignition. Acceptance of this factor would obviate the necessity of recording a variable torque.

By means of this invention an absolute value in foot-pounds can be assigned to friction sensitive materials. The apparatus can be easily fabricated from drawings and will enable a test activity to produce test data which can be duplicated by any other test facility using the apparatus.

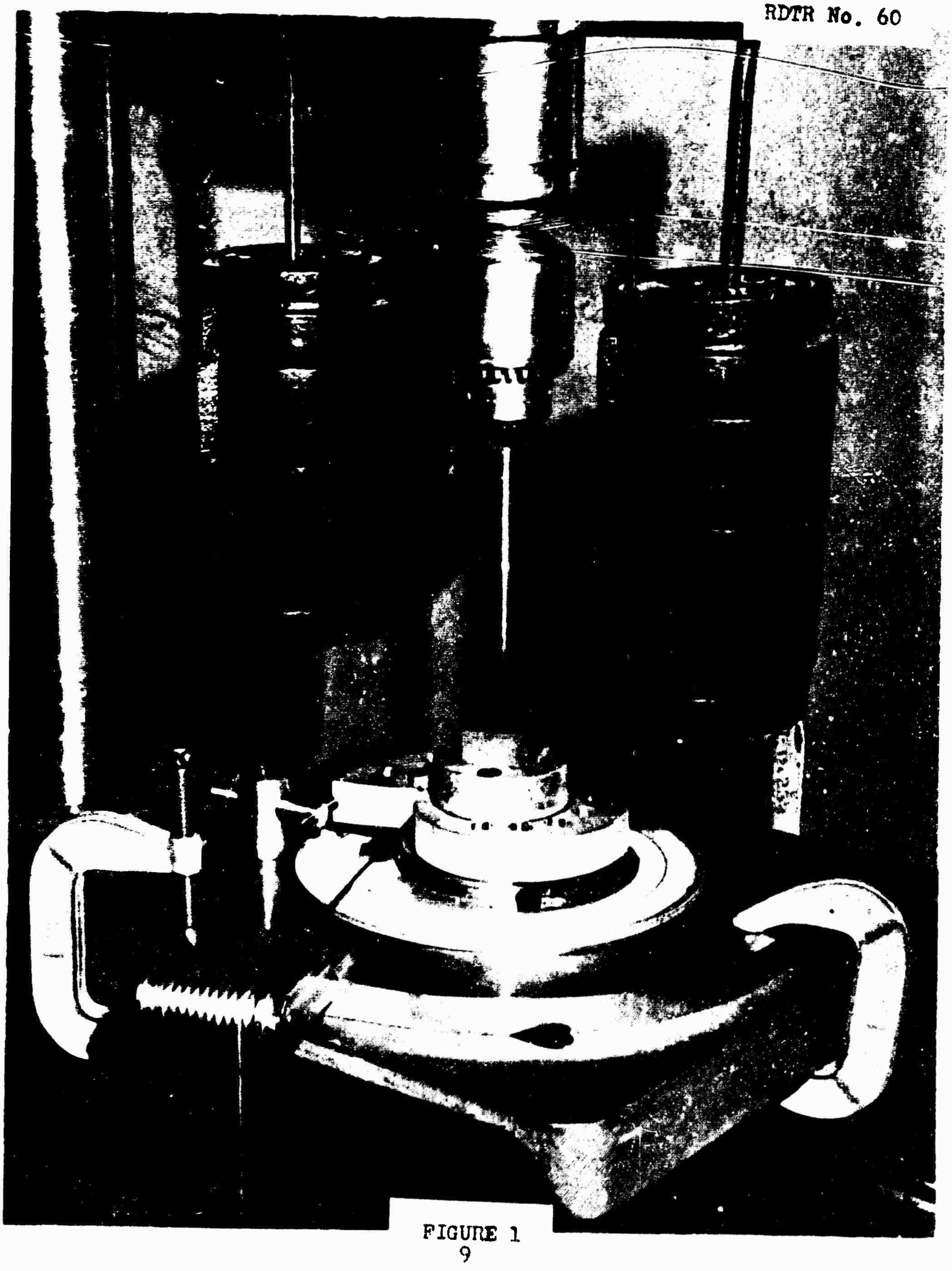

FIGURE 1

TABLE 1
CHART FOR RDT-2822

Rotation in Degrees	Torque Arm Length in Inches
0°	1.25000
5°	1.26905
10°	1.28810
15°	1.30715
20°	1.32620
25°	1.34525
30°	1.36430
35°	1.38335
40°	1.40240
45°	1.42145
50°	1.44050
55°	1.45955
60°	1.47860
65°	1.49765
70°	1.51670
75°	1.53575
80°	1.55480
85°	1.57385
90°	1.59290
95°	1.61195
100°	1.63100
105°	1.65005
110°	1.66910
115°	1.68815
120°	1.70720
125°	1.72625
130°	1.74530
135°	1.76435
140°	1.78340
145°	1.80245
150°	1.82150
155°	1.84055
160°	1.85960
165°	1.87865
170°	1.89770
175°	1.91675
180°	1.93580
185°	1.95485
190°	1.97390
195°	1.99295
200°	2.01200
205°	2.03105
210°	2.05010
215°	2.06915
220°	2.08820
225°	2.10725

TABLE 1 (Cont'd)

Rotation in Degrees	Torque Arm Length in Inches
230°	2.12630
235°	2.14535
240°	2.16440
245°	2.18345
250°	2.20250
255°	2.22155
260°	2.24060
265°	2.25965
270°	2.27870
275°	2.29775
280°	2.31680
285°	2.33585
290°	2.35490
295°	2.37395
300°	2.39300
305°	2.41205
310°	2.43110
315°	2.45015
320°	2.46920
325°	2.48825
330°	2.50730
335°	2.52635
340°	2.54540
345°	2.56445
350°	2.58350
355°	2.60255
360°	2.62160

Each degree rotation represents .00381" increase in the torque arm. Inch ounces may be determined by multiplying ounces weight times the torque arm length in inches.

TABLE 2

Showing that the varibles may be changed with very slight effect on the friction sensitivity of A1A when expressed in foot pounds of energy:

Torque			Pounds		Ignition	
Load Ounces	Deflection Degrees	RPM	Load on Friction rod	Time to fire Seconds	Energy Ft.Lbs.	Notes
8.30	79	2400	14	2.0	34.48	Burns
8.30	79	2400	14	2.0	34.48	Burns
4.27	318	2400	10	2.2	36.63	"
12.29	46	2400	20	1.8	36.68	"
12.29	46	2400	20	1.9	38.72	"
8.30	173	2400	15	1.9	37.35	"
8.30	44	3600	10	1.6	36.96	"
4.27	Full Scale	3600	10	1.7		"
8.30	108	3600	20	1.3	35.20	"

TABLE 3

Showing that the variables may be changed with very slight effect on the friction sensitivity of RAPEC when expressed in:

Foot pounds of Energy

Torque			Pounds		Foot Pounds of	
Load Ounces	Deflection Degrees	RPM of Press	Load on Press	Firing Time Seconds	Energy to cause sample to fire	Notes
8.30	43	3600	25	2.9	66.79	Detonates
8.30	44	3600	20	2.8	64.70	"
4.27	341	3600	10	3.1	66.40	"

TABLE 4

Comparing the friction sensitivity of a few pyrotechnic mixtures.

Torque			Pounds	Firing	Foot Pounds	Composition	
Load Oz.	Deflection Degrees	RPM of Press	Load on Press	Time Seconds	Of Energy to Cause Sample to Fire	Tested	Notation of Observation
8.30	44	3600	10	1.6	36.96	A1A	Burns
8.30	44	3600	20	2.8	64.70	RAPEC	Detonates
8.30	212	3600	27	115	3814	Mk 24 Ejection Comp.	Smokes
8.30	216	3600	27	110	3894	Mk 24 Ejection Comp., Dried Overnight in Vacuum at 50°C	Burns
4.27	321	3600	17	5.4	94.75	Stabilized Red Phosphorus	Burns
8.30	53	3600	27	120	2845	Hi-Skor Smokeless Powder	Burns
8.30	75	3600	27	3.4	87.37	90% Red Phosphorus + 10% Hi-Skor Smokeless Powder	Detonates
8.30	74	3600	27	3.5	85.09	"	"
8.30	125	3600	27	300	5625	M-10 Single Base Propellant Powder	Not Set Off
8.30	85	3600	27	3	7255	M-10 Single Base Propellant + 10% Red Phosphorus	Detonates
8.30	83	3600	27	2.8	71.82		"
8.30	330	3600	27	5	204.3	Mk 24 Flare Comp.	Flash
8.30	325	3600	27	5.2	210.9	"	"

TABLE 4 (Cont'd)

Torque			Pounds	Firing	Foot Pounds	Composition	
Load Oz.	Deflection Degrees	RPM of Press	Load on Press	Time Seconds	Of Energy to Cause Sample to Fire	Tested	Notation of Observation
12.29 12.29	181 186	3600 3600	27 27	27 25	1262 1229	Mk 25 Starter Mk 25 Starter	Flash Flash
12.29 12.29	108 160	3600 3600	27 27	27 27	664 661	Mk 24 Delay Comp. FDM8	Burns Burns
12.29 12.29	94 96	3600 3600	27 27	3.9 3.8	151 148	Mk 68 Flare Comp. "	Slight Detonation
4.27 4.27	6 5	3600 3600	27 27	3.2 3.1	34.02 33.05	Mk 2-0 Color Burst with Fine Parlon	Flash "
4.27 4.27	7 7	3600 3600	27 27	4.5 4.6	48.19 49.24	Mk 2-0 Color Burst with Coarse Parlon	Flash "
8.30 8.30	45 53	3600 3600	27 27	24. 23.5	555 555	Mk 68 Smoke Comp. "	Smoke "
8.30 8.30	312 312	3600 3600	27 27	31.9 32	1267 1271	Mk 24 First Fire "	Flash "
12.29 12.29	105 105	3600 3600	20 20	7.7 7.6	306.5 302.5	50% Mk 58 Starter & 50% Mk 58 Candle Mix	Burns "
12.29 12.29	115 110	3600 3600	20 20	21 21.2	852 853	Mk 58 Candle Mix "	Burns "
4.27 8.30	315 325	3600 3600	26 26	3.8 1.9	78.06 77.04	Tracer Mix MIL-C-18836 "	Snap-Crackle Flash

TABLE 4 (Cont'd)

Torque			Pounds	Firing	Foot Pounds	Composition	
Load Oz.	Deflection Degrees	RPM of Press	Load on Press	Time Seconds	Of Energy to Cause Sample to Fire	Tested	Notation of Observation
4.27	63	3600	27	300	3747	Comp CH-6	Did not Fire
4.27	303	3600	27	600	12,074	"	"
4.27	300	3600	27	900	18,328	"	"
0.30	45	3600	27	600	502	Tetryl 1	Did not Fire
0.30	20	3600	27	1200	937	"	"
0.30	25	3600	27	1800	1425	"	"
8.30	280	3600	27	300	11,321	TNT	Did not Fire
8.30	281	3600	27	300	11,343	TNT	"
8.30	280	3600	27	300	11,321	TNT	"

LIST OF DRAWINGS

ACKNOWLEDGEMENT

Mr. Paul Scott and Mr. Carroll Morrison designed the torque converter. Mr. Ralph Chipman furnished the mathematical formulas. The original idea for this type of apparatus resulted from a brain storm session between Carl Armour of the U. S. Naval Ammunition Depot and Mr. Jerry Weingarten of Picatinny Arsenal.

The remainder of this apparatus resulted from the collaboration of the authors of this publication.

U. S. NAVAL AMMUNITION DEPOT
CRANE, INDIANA

9 JULY 1965

ERRATUM

RDTR NO. 60
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CARL ARMOUR

CHANGE:

Page 14, Table 4, Column 6 "Foot Pounds Of Energy To Cause Sample To Fire", for composition M-10 Single Base Propellant + 10% Red Phosphorous, change the figure 7255 to read 72.55